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Meyer, Harry

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Introduction

Our Healthcare and Public Health (HPH) sector is vast, complex and essential to virtually all other sectors of our nation's infrastructure. Without a healthy workforce modern society quickly grinds to a halt. The often messy networks of healthcare providers, insurance companies, emergency departments, pharmaceutical manufactures and other equally important actors are bound together in fragile alliances to maintain and restore basic health. Thus the HPH sector becomes an important cog in the wheel of infrastructure, if for no other reason than everyone needs healthy workers.

In looking at the HPH Sector as an element of critical infrastructure it is important to note that within the sector there are two very different functions with divergent goals. While healthcare and public health are both in the same sector, they are different disciplines. The fundamental goal of healthcare is to provide medical care to sick or injured patients. The ownership of the subsystems that make up the healthcare system tends to be privately held and is a combination of for profit and not for profit entities. Public health on the other hand, is a government run system. It is not so much concerned with medical care as it is with the health of populations. It seeks out the threats to the population's health and develops intervention strategies to mitigate those threats. The inherent differences between the healthcare and public health systems that comprise the HPH sector make assessment of this sector challenging.

This paper examines the challenges associated with doing a comprehensive assessment of the HPH Sector and then focuses attention on the healthcare system and the hospitals as one of its subsystems. In particular it will discuss how hospitals are intricately linked to other sectors of critical infrastructure. In a modern, technological society, hospitals must depend on services provided by the power, water, energy, information technology/telecommunications (IT/telecom) and transportation sectors. As Hurricane Katrina demonstrated, when key infrastructure sectors in a community fail, a hospital quickly goes from being a center that cares for sick and injured patients to a lifeless facility that can not perform its most basic functions. Part of the challenge during a disaster is the necessity to manage the conflict that arises when services are provided under disaster authorities. In this circumstance there is no charge to patients for government-provided healthcare which can slow recovery by discouraging providers to return to their communities and reopen their practices.

Since hospitals are dependent upon other sectors, preserving their ability to function and treat patients in an all hazard environment becomes a prominent goal of emergency preparedness activities. In this regard, critical infrastructure protection and emergency

preparedness programs have an overlapping interest in promoting resiliency that enables the sector to operate in a multi-threat environment.

Health and Public Health Sector as an element of Critical Infrastructure

The US Department of Health and Human Services (HHS) has been assigned the responsibility as the nation's sector specific agency for Healthcare and Public Health by Homeland Security Presidential Directive 7 (HSPD 7), and in May of 2007, HHS completed its first sector specific plan. The HPH Sector Specific Plan (SSP) created a framework for integrating Healthcare and Public Health into the National Infrastructure Protection Plan as required by HSPD-7. To accomplish this HHS has created strong public/private partnerships that provide input directly into the HPH SSP through private sector Healthcare Coordinating Councils.[1]

The HPH SSP made tremendous gains in defining the sector and identified areas for future consideration. It also recognized a number of challenges that make a comprehensive nationwide assessment of the sector difficult. This paper will address some of the critical barriers that make sector wide assessments particularly challenging and then proffer a strategy to help mitigate some of these challenges. While this is not an all inclusive list of obstacles these are the issues that make a sector wide assessment particularly thorny, especially if only a top down assessment strategy is followed. The six challenges that will be discussed in this paper are:

- The vastness and complexity of the Healthcare System
- The hierarchal nature of systems
- Organizational differences and variation between public health jurisdictions
- Lack of an agreed upon architecture
- Modeling appropriate relationships
- The ever evolving nature of the Healthcare and Public Health Sector

The Vastness and Complexity of the Healthcare System

To say that the healthcare system is complex is certainly an understatement. Within the United States there are 13 million health care providers, 6 thousand hospitals, 700 thousand ambulatory care facilities, 6 thousand home healthcare agencies, 70 thousand pharmacies, 170 thousand laboratories and 2 thousand pharmaceutical manufacturers.[2] The vastness and complexity of the healthcare system makes a comprehensive assessment of the HPH Sector extremely challenging. The fact that private ownership of healthcare assets is distributed between the for profit and not for profit portions of the economy, and public health is a government provided service adds to the complexity within the sector.

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[1] Homeland Security Presidential Security Directive Seven (HSPD-7). 17 December 2003.
[2] US Department of Health and Humans Services. *Public Health and Healthcare Sector Specific Plan; Critical Infrastructure and Key Resources Sector Specific Plan as input to the National Infrastructure Protection Plan (for official use only)*. p-11. May 2007

The Hierarchal Nature of Systems

Practitioners working within the Healthcare and Public Health Sector frequently refer to the sector as a system. But while healthcare seems to meet the definition of a system as discussed in "General System's Theory" it is not quite as clear with public health.

The principle of "General System's Theory" as proposed by Ludwig von Bertalanffy in 1931 seems to apply nicely to the healthcare sector and his theory can be used to give us some structure and insight. Bertalanffy, whose work was inspired by the 18th Century Gestaltist philosopher Georg Wilhelm Friedrich Hegel was particularly interested in Hegel's idea, that the whole was more than the sum of the parts. This eventually led to Bertalanffy's "General System's Theory". A biologist by trade, Bertalanffy described systems in terms of supra-systems and subsystems. He believed that a system needed four things in order to exist. It needed parts, elements, or variables; it had to have attributes; and there had to be internal relationships between the components and finally, a system had to exist within an environment.[3]

General System's Theory describes two types of basic systems. The first was a closed system. A closed system is one that does not interact with its environment. System's that do not interact with their environment eventually die. The second type of system was an open system. An open system is one that interacts with the environment, it takes inputs from the environment, and it has throughputs and outputs. Hospitals can be viewed as open systems, they take inputs from the community in the form of sick patients, system throughput can be viewed in terms of patient care and finally there are outputs in the form of treated people. But there are other inputs that are necessary to enable a hospital to treat people as well; they need medical supplies (dependent upon the transportation sector); potable water (dependent upon the water sector); electricity (dependent upon the power sector); fuel (dependent upon the energy sector) ; and communications capabilities (dependent upon the IT/telecom sector). Since several systems are sharing a common environment and all are taking their inputs directly from and sending outputs directly back to the same common environment, each system ends up interacting with the environment in very discrete and complex ways. When we try to apply the "General System's Theory" definition to public health however; it becomes problematic. Public health can not be easily viewed in terms of inputs and outputs; rather practitioners in the discipline tend to view public health in terms of causation linkages. It is for this reason that this paper is focusing on the healthcare system.

There are times when we want to look at a system in terms of total inputs and total outputs. In these situations we are not necessarily concerned with all of the discrete interactions between the subsystems. This approach, just focusing on the total inputs and outputs is referred to as the black box approach in cybernetics.

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[3] Littlejohn. *Simple System Model*. Retrieved http://www.tcw.utwente.nl/theorieenoverzicht/Theory%20clusters/Communication%20Processes/System_Theory.doc/ 19 Feb 2008.

There are times however, when we are concerned with the interactions between the subsystems. We want to see how one subsystem impacts another. For example at the hospital level we may want to see how the electrical system relates to the water system and the hospitals medical gas distribution system interfaces with other hospital systems. This type of approach is referred to as a white box systems approach.

The inherent nature of systems is that they are hierarchal, the higher you go in the hierarchy the more you must study problems in the abstract. For example, we can view healthcare as a supra-system and hospitals as one of its subsystems. Likewise the hospitals can be viewed as a supra-system and the electrical distribution and supply chain management systems can be seen as subsystems of the hospitals. It is in this sense that systems are hierarchal. While it's possible to study a single hospital and identify multiple vulnerabilities by studying the discrete interaction between its subsystems, as we aggregate this information the ground truth becomes less and less clear. We may see common threads of information and trends between facilities but we can not say with any degree of certainty that these vulnerabilities apply uniformly across the system. One of the lessons learned from Hurricane Katrina was that hospital auxiliary generators and electrical switching rooms are frequently located in basements and while we may be able to make generalized statements that many or most hospitals place their auxiliary generators in basements, it is not a universal truism.

As information about vulnerabilities are rolled up from subsystems to supra-systems the information becomes more abstract and less useful, particularly when it comes to funding specific mitigation projects to eliminate specific vulnerabilities.[4]

Organizational differences and variation in public health jurisdictions

Adding to the complexity of the HPH sector is the fact that no two public health jurisdictions in the United States are identical. In fact, management of public health through health departments is distributed across 3000 independent city and county health departments and local boards of health, 59 State and territorial health departments, a variety of tribal health departments and 40 different Federal agencies/departments.[5]

There is variation not only in how state health departments are organized but also in the services they deliver. Even within a State there can be considerable differences in how public health services are organized and delivered. In the Commonwealth of Pennsylvania for example, communities are linked to the state health department through six health districts. Each health district is responsible for oversight of six to thirteen counties. The state operates fifty seven health centers and the Pennsylvania Department of Health provides oversight to ten county and municipal health departments that provide service to 40% of the Commonwealth's population.

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[4] Cybernetics and System Theory, Principia Cybernetica Web; retrieved http://pespmc1.vub.ac.be/CYBSYSTH.html 5 Sep 2006

[5] Wasserman, Jeffrey et. Al. *Organizing State and Local Health Departments for Public Health Preparedness*. Prepared by the RAND Center for Domestic and International Health Security for the US Department of Health and Human Services. 2006.

In the five county area that makes up Southeastern Pennsylvania, an area that is made up of a combination of urban, suburban and rural communities there is one city health department, three county health departments and two counties do not have a health department.

Political and economic forces shape health service delivery and the result is a mixed bag of organizations and government provided services. Just as no two states are organized the same, neither are county or municipal health departments. The emergent networks of Healthcare and Public Health creates significant challenges in conducting a meaningful nationwide sector assessment.[6]

Lack of an agreed upon architecture

Currently there is no universally agreed upon architecture of the HPH Sector, and while the HPH Sector Specific Plan was a good first step in identifying key components of the sector it is far from comprehensive. People who work in the healthcare industry recognize the sector, but there remains no mutually agreed upon architecture.

At HHS the Assistant Secretary for Preparedness and Response (ASPR) has been instrumental in trying to institutionalize the framework and terminology of the HPH Sector. A team of HHS contractors has been mapping the sector and has started to create a framework for a standard taxonomy. While still a work in progress the following taxonomy has started to emerge:

Sector: A logical collection of systems, networks, and organizations that provide related goods and services to the economy, government or society (example: Healthcare and Public Health Sector).

Domain: A set of services within a sector sharing a common mission or purpose (example: Population Health Management).

Capability: The ability to perform designated activities that fulfill a given set of requirements within a sector's domain (example: Surveillance)

Function: A set of activities or operations that are carried out to provide sector goods or services (example: Situational Awareness)

Resource: A person, asset or material required to perform specified function (Bio Watch Pathogen Sensor)

External Entity: An organization outside the sector that provides resources necessary to perform a specified function within the sector (Example: Energy would be

[6] Pennsylvania Department of Health. Retrieved http://www.dsf.health.state.pa.us/health/site/default.asp 19 Feb 2008

an external entity that supplies the resource of power to a Bio Watch sensor that performs the function of situational awareness).

Modeling appropriate relationships

One of the beauties of network analysis is its flexibility. Since networks can be depicted as abstract mathematical graphs, it is possible to use them as tools to model a variety of things in the real world. In its most simple form a network map contains two or more nodes that are connected by links, where links represent some type of relationship between the nodes. The user defines the nodes and the links as part of the analytic process. The key to using this methodology effectively is correctly defining the right nodes and right links. Because the HPH Sector is so diverse and complex, it is difficult to find sector wide common denominators.

While it may not be possible to find an appropriate sector wide relationship to model, it should be possible to take one of the sector's domains, such as medical supply chain and model it using network analysis. By limiting the scope to one or two domains the problem becomes less complicated and more meaningful models can be developed thus gaining greater insight into a segment of the sector.

The ever evolving Healthcare and Public Health Sector

Trends in healthcare delivery continue to shape the HPH Sector, which like most other critical infrastructure sectors continues to emerge. The following is a brief synopsis of some of the major trends that are impacting the sector's evolving structure.

1960-2000

- The percentage of gross national product (GDP) spent on healthcare has increased from 5.1% to 14%

1975-1995

- The national number of acute care hospital beds has declined by 22%
- Hospital admissions have declined by 5%
- The average length of stay per patient has declined by 33%
- Inpatient surgical procedures have declined by 27%

1950-Present

- The number of Americans over 65 years old has tripled and by 2035 this number will increase to approximately 80 million in the United States.

We have also seen a nationwide decline in the number of hospital emergency departments and acute care facilities, while at the same time we have seen increased demand for patients requiring intensive care.[7]

[7] Retrieved from http://www.cdc.gov/ncidod/eid/vol17no2/jarvis.htm . 15 Feb 2008

We have also seen major changes in healthcare spending. Medicare spending grew at its fastest pace since 1981 due to the new prescription drug plan. Plus we are seeing deceleration in employer payments for health insurance, in part because Medicare is paying a larger share and because private insurance companies are now playing a larger role in Medicare. Since private insurance companies have higher administrative costs less money is being spent on hospitals, doctors and nursing homes.[8]

The impact of these trends means that in the future we will have fewer hospitals with less emergency departments. We can expect to see more and larger intensive care units and greater severity of illnesses in hospitals' inpatient populations. Additionally, we can expect greater reliance on home care, long term care and assisted living.

Mitigating Challenges

One way to mitigate some of the assessment challenges identified in this paper is to use a risk based approach and focus on one or two domains in a limited geographic area. By taking a system's approach and focusing attention on a portion of the HPH sector we have the luxury of analyzing the discrete interactions between subsystems at the grassroots level, thereby eliminating some of the issues associated with complexity, vastness and jurisdictional variation. By limiting the scope of our assessment, issues such as determining appropriate relationships to model become more workable. Additionally, by keeping within the framework of a defined taxonomy we start to better define the amorphous HPH Sector.

Delaware Valley Model Based Risk Analysis Project (Del Val MBRA Project)

At this time there is no widely accepted, probability based risk assessment methodology that assesses the impact of a large scale disaster on a hospital. Over the years several different assessment tools have been developed, but most fall short of meeting the National Infrastructure Protection Plan's baseline criteria for risk calculus (Risk = Consequences * Vulnerabilities * Threat).[9]

The Delaware Valley, a densely populated area that covers Southeastern Pennsylvania, Northern Delaware and Southern New Jersey is an ideal location to conduct a limited study of the Direct Patient Services and Medical Supply Chain Domains. The Region contains a mix of urban, suburban and rural communities with a large concentration of tertiary hospital beds, Healthcare is currently one of the largest industries in Southeastern Pennsylvania and the area is particularly known to have one of the most competitive healthcare markets in the nation.

The US Department of Health and Human Services (HHS) is participating in a study with the Delaware Valley Healthcare Council (DVHC) (the areas local hospital association) to conduct the first field test of Model Based Risk Analysis (MBRA) in the HPH Sector. After benchmarking several other critical infrastructure protection

[8] Pear, Robert. *Health Spending Exceeded Record $2 Trillion in 2006, NY Times.* 8 Jan 2008
[9] U. S. Department of Homeland Security, *National Infrastructure Protection Plan*. P.36. 2006

methodologies, MBRA was selected as the methodology of choice because it was the closest in meeting the NIPP's baseline criteria for risk calculus. This project is limiting its scope of work to look specifically at hospitals as a subsystem of the healthcare system in a defined geographic region.

The elements of risk calculus for this project are defined as follows:

Risk = Consequences (C)*Vulnerabilities (V)*Threat (T) [R=C*V*T]

Consequences (C) are defined as a hospital's loss of functions due to an adverse event generated by the exploitation of vulnerabilities. Downstream consequences associated with specific vulnerabilities plays a vital role in risk management calculations.

Vulnerabilities (V) are defined as weaknesses that would degrade hospital functions. These vulnerabilities include key dependencies on: power (p); water (w); energy (e); IT/Telecom (i) and transportation (t)

Threat (T) is defined as the likelihood that any of these key dependencies would be interrupted: [T=p*w*e*i*t].

The Del Val MBRA Project will study five different hospitals in the Delaware Valley and examine the discrete interactions between the subsystems using fault and event tree analysis. The purpose of using fault/event trees will be to identify specific vulnerabilities and specific losses of hospital functions (consequences) caused by a disaster that disrupts services in the following sectors: power (p), water (w), energy (e), IT/telecom (i) and transportation (t). Additionally, through network analysis the project will examine the medical supply chain and the impact that disruption of services from p*w*e*i*t will have on the five selected hospitals. While the project is still in its infancy, the following is a statement of the project's goal, objectives, expected outcomes and potential benefits.

Project Goal: The project's goal is to improve hospital survivability and enhance the HPH sector's resilience in an all hazard threat environment.

Objective: To field test Model Based Risk Analysis methodology and determine its applicability to the HPH Sector as a means to improve hospital survivability and enhance the healthcare sector's resiliency in an all hazard threat environment.

Expected Outcome #1: Determine critical distributors and suppliers in the medical supply chain through network analysis

Expected Outcome #2: Use fault and event tree analysis to identify major weaknesses (vulnerabilities) of a hospital

Expected Outcome #3: Identify the most significant functions (consequences) that are lost when dependent sectors are compromised

Expected Outcome #4: Determine the most appropriate resource allocation strategy to mitigate risk

Potential Benefit: The movement of hospital patients either before or after a disaster exposes them to increased harm and will likely result in unnecessary deaths. By developing a risk based approach to hospital resiliency and risk mitigation it is possible to engineer disaster resilient hospitals that can deliver patient services in an all hazards environment.

Conclusion

In conclusion, the inherent differences between healthcare and public health, both in their goals and how they deliver their services causes significant problems in conducting a comprehensive sector assessment. When healthcare services are delivered in an all hazard environment there is an inherent need to balance patient services with business functions. During disasters there is a general expectation that hospitals should provide services for the public good regardless of an individual's ability to pay, yet providing such services could compromise the financial viability of the institution. This presents natural conflict between the public and the private sectors.

There has been a considerable collaboration between the public and private sectors through the Healthcare Coordinating Council to define a path ahead to protect HPH Sector. Despite these gains the issues of:

- Vastness and complexity of the healthcare system
- The hierarchal nature of systems
- Organizational differences and variation in public health jurisdictions
- Lack of an agreed upon architecture for the sector
- Modeling appropriate relationships
- Ever emerging health and public health sector

create systemic problems that make a top down, comprehensive assessment of the sector impractical. While a top down assessment of the HPH Sector may not be practical, a bottom up strategy that looks at specific subsystems within a limited geographic area can be useful. By following a bottom up strategy we can gain greater knowledge of the discrete interactions that take place between subsystems in the larger Healthcare System and in doing so uncover weaknesses and vulnerabilities that may have otherwise gone unnoticed. By using a sound risk based assessment methodology, funds can be better targeted to mitigate risk and build appropriate redundant systems that will allow facilities to withstand the challenges of an all hazard threat environment. By increasing a hospitals ability to continue to function and bill for services throughout a disaster it will be possible to lessen the inherent conflict between the public and private sectors during future disasters.

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